

James Webb Space Telescope: The First Light Machine

H. Philip Stahl

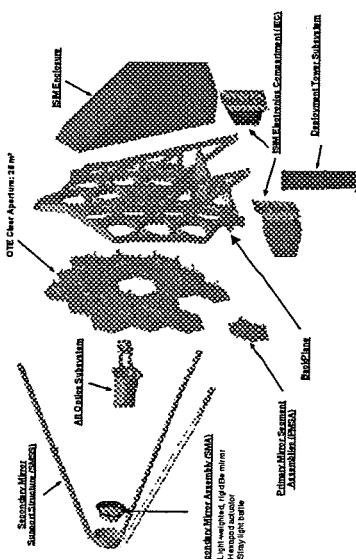
NASA Marshall Space Flight Center, AL 35812

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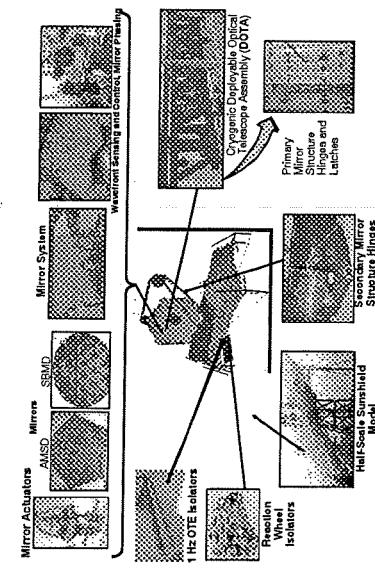
ABSTRACT

Scheduled to begin its 10 year mission no sooner than 2013, the James Webb Space Telescope (JWST) will search for the first luminous objects of the Universe to help answer fundamental questions about how the Universe came to look like it does today. At 6.5 meters in diameter, JWST will be the world's largest space telescope. This talk reviews science objectives for JWST and how they drive the JWST architecture, e.g. aperture, wavelength range and operating temperature. Additionally, the talk provides an overview of the JWST primary mirror technology development and fabrication status.

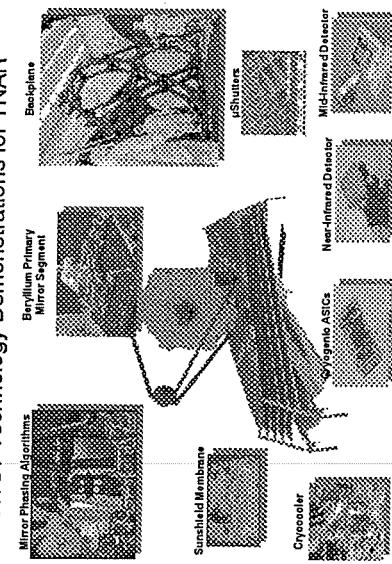
OTE Architecture Concept



Investments Have Reduced Risk



JWST Technology Demonstrations for TNAB



Cochlear Implants in Children with Cleft Palate 11

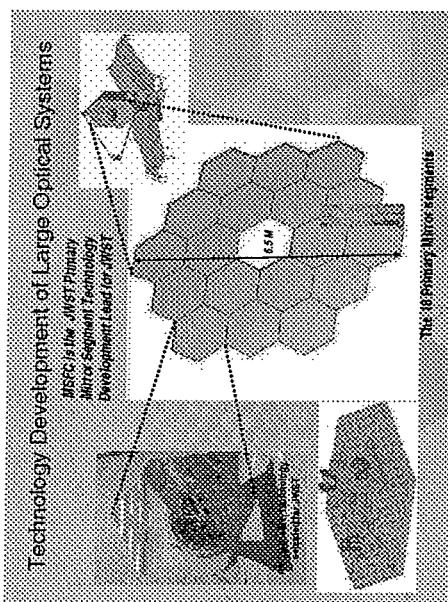
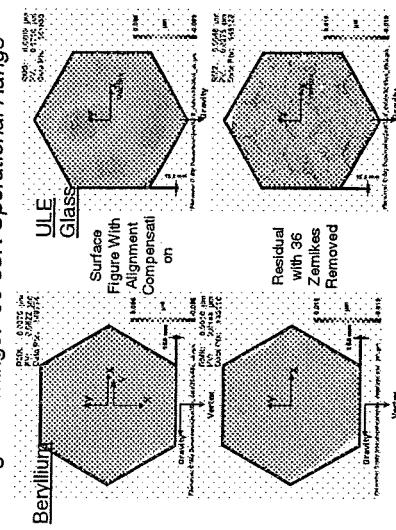
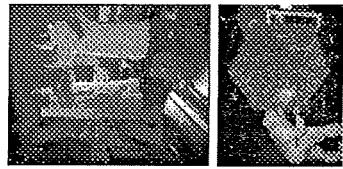


Figure Change: 30-55K Operational Range



AMSD - Ball & Kodak

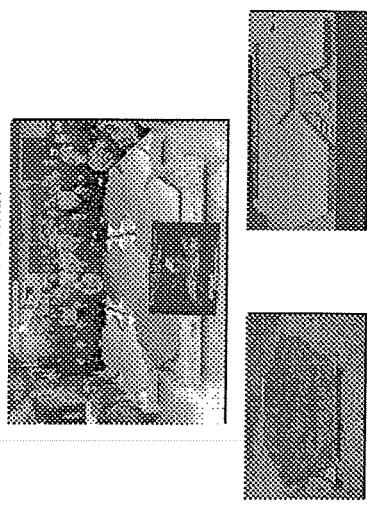


Advantages of Bandwidth

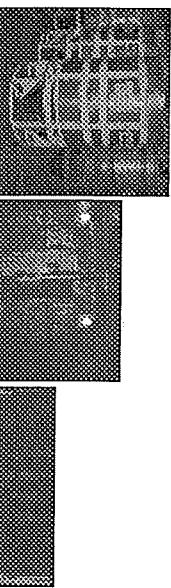
Very High Specific Stiffness – Modulus/Mass Ratio
Saves Mass – Saves Money

High Conductivity & Below 100K, CTE is virtually zero.
Thermal Stability

Brush Wellman



Substrate Fabrication



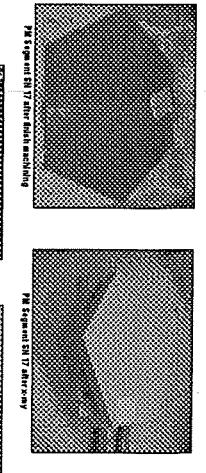
PM Segment #1 19-20
prior to bonding

PM segments #1 19-20
prior to bonding

PM Segment #1 19-20
prior to bonding

Movie

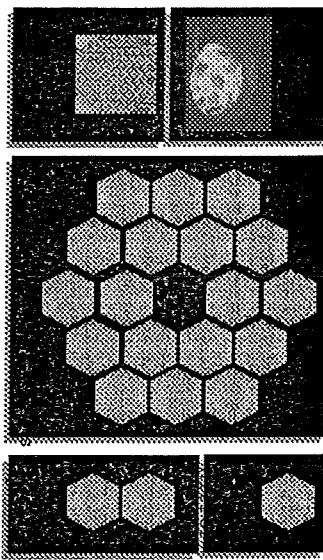
Fabrication Process



PM Segment #1 19-20
prior to bonding

Quality Control X-Ray Inspection

Status = Flight Mirror Blank Fabrication Complete



PM segments #1 19-20
prior to bonding

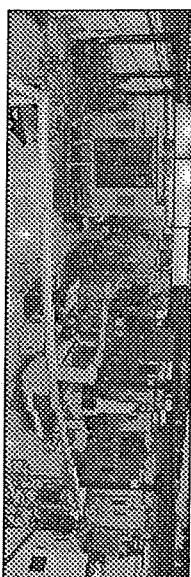
PM segments #1 19-20
prior to bonding

Movie

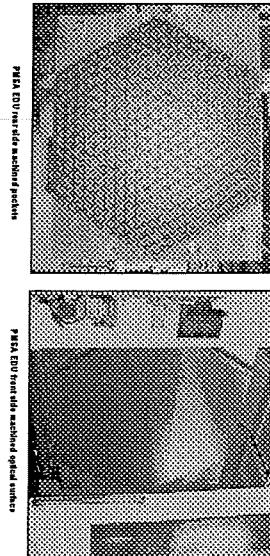
Axsys Technologies

Axsys Technologies

PMSA Engineering Development Unit



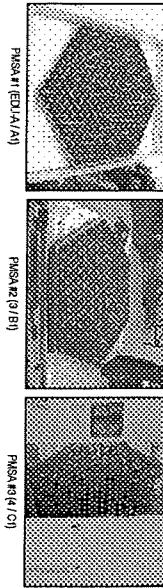
8 CNC Machining Centers



PM Segment #1 19-20
prior to bonding

Axsys Technologies

Batch #1 (Pathfinder) PM Segments



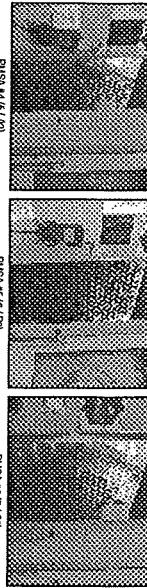
PM Segment #1 19-20

PM Segment #1 19-20

PM Segment #1 19-20

PM Segment #1 19-20

Batch #2 PM Segments



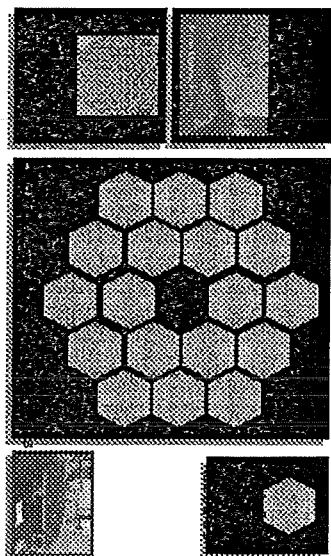
PM Segment #1 19-20

PM Segment #1 19-20

PM Segment #1 19-20

PM Segment #1 19-20

Status = Flight Mirror Lightweighting Complete



Axsys Technologies

PM Segment #1 19-20

PM Segment #1 19-20

PM Segment #1 19-20

PM Segment #1 19-20

8 CNC Machining Centers

PMSA Engineering Development Unit

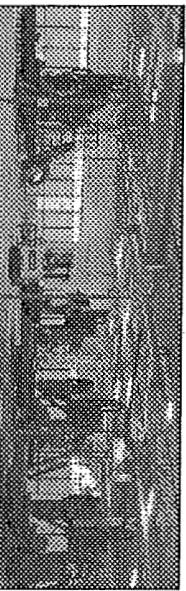
Axsys Technologies

PM Segment #1 19-20

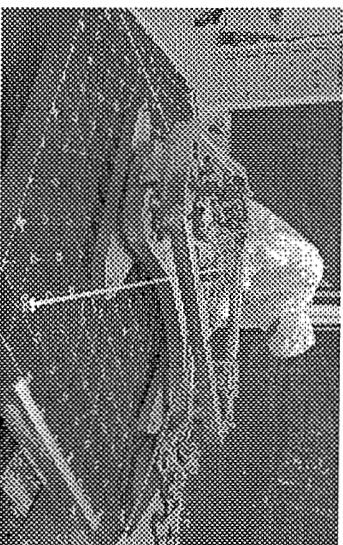
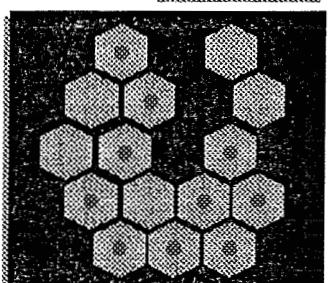
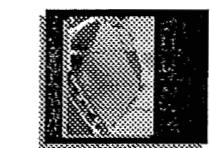
PM Segment #1 19-20

PM Segment #1 19-20

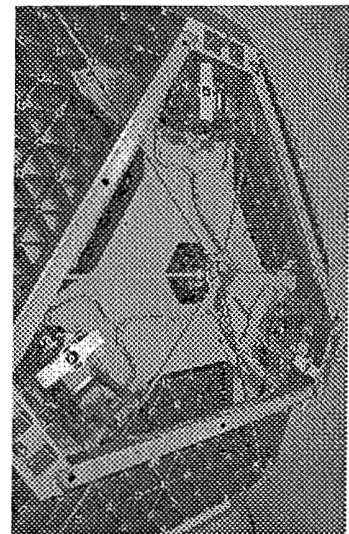
PM Segment #1 19-20



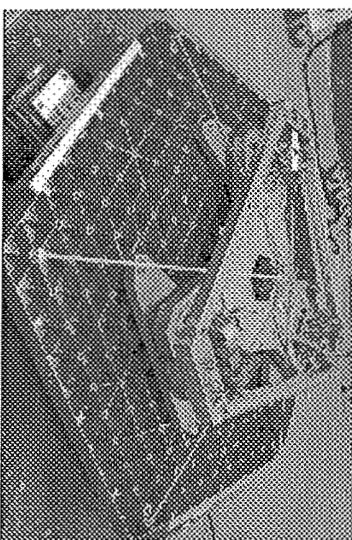
Production Preparation – CCOS Machines
1st – 4th CCOS machine bases assembled and operational
5th – 8th CCOS machines received and in storage – installation to start 4/4/05



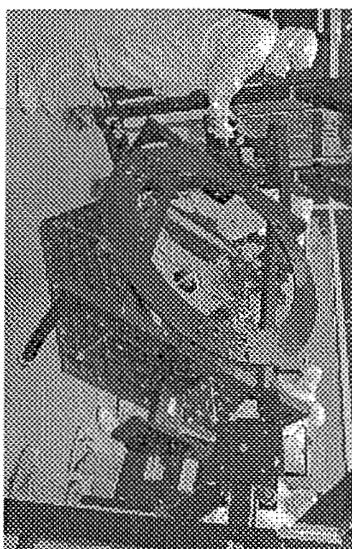
PMSA Assy



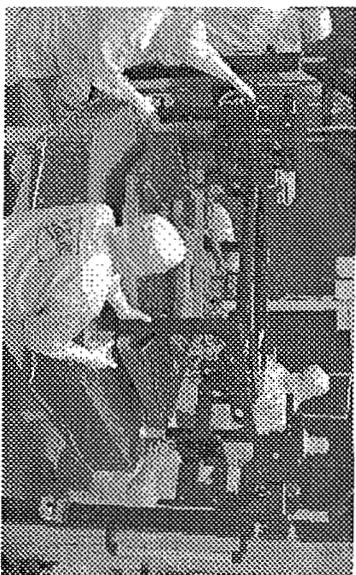
PMSA Assembly



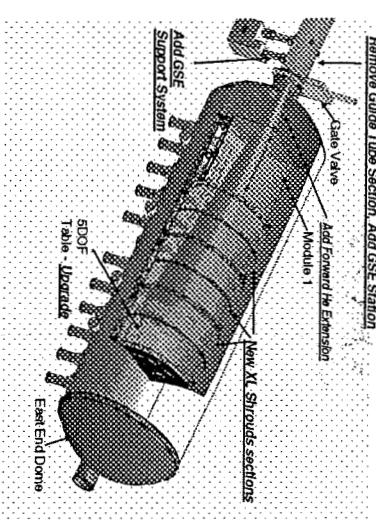
PMSA Assembly on its way to Optical Test



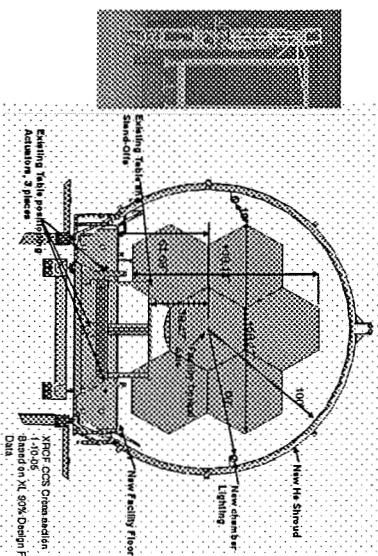
PMSA Assembly on its way to Optical Test



MSFC JWST Support Effort – Facility Upgrades

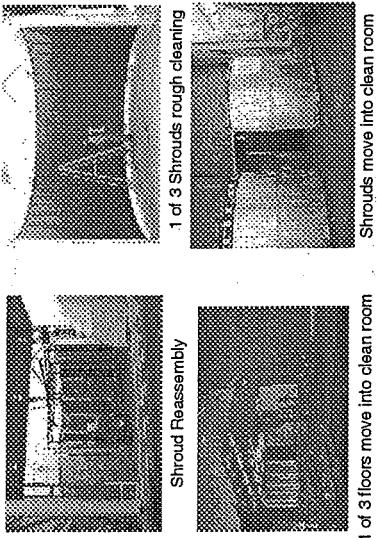


MSFC JWST Support Element - BSA Test Configuration

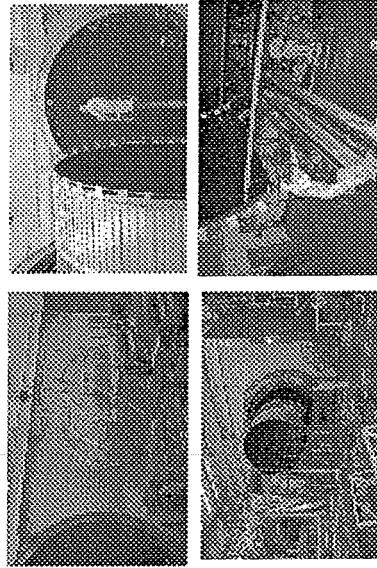


XRCF Facility Upgrades in FY '05-06

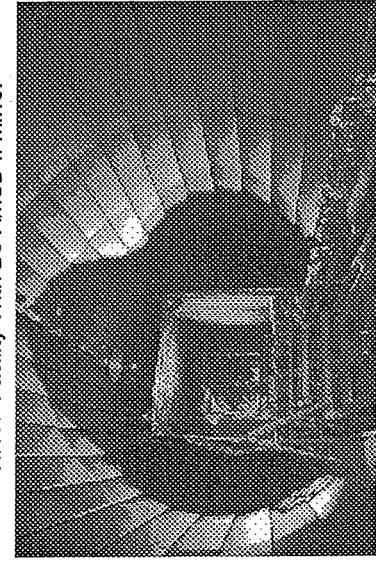
XRCF CCS Assembly



XRCF CCS Fit-Check

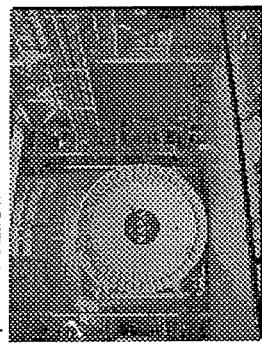


XRCF Facility With Be AMSD II Mirror

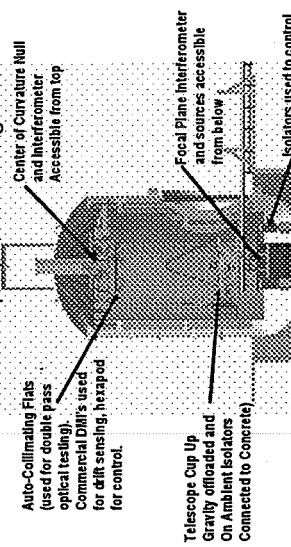


JWST I&T

JSC Chamber A
Chamber Size
55' diam, 117' high
Existing Shrouds LN₂ shroud, GHe panels
Chamber Cranes 4x25t fixed, removable
Chamber Door 40' diam
High bay space ~102'Lx71'W



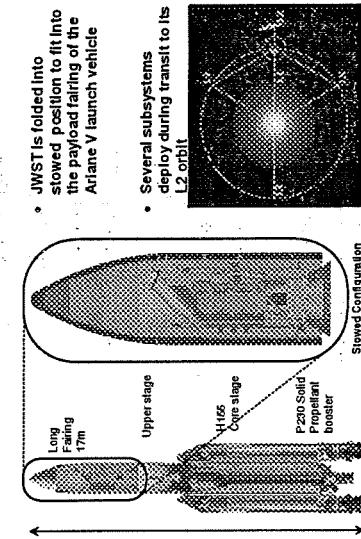
JSC "Cup Up" Test Configuration



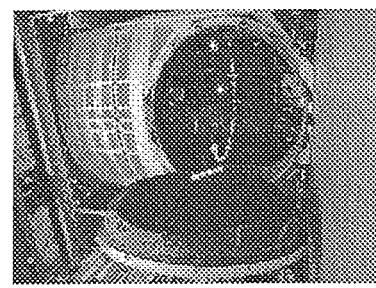
JSC Size, Accessibility, and Large Side Door Access
Make it Well Suited for This Configuration



JWST Launch and Deployment

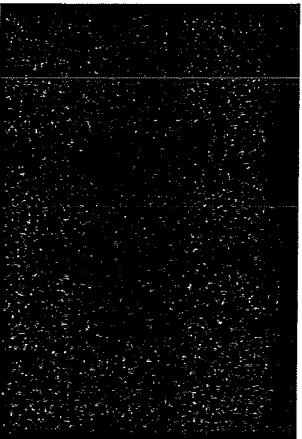


JSC Chamber A Thermal Vacuum Facility

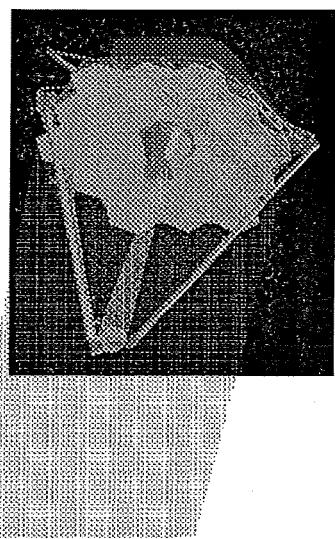


Chamber A was used for Apollo Landers and already includes Nitrogen and Helium systems. Plan is to upgrade it with a new Helium Inert Shroud and Helium refrigerators.

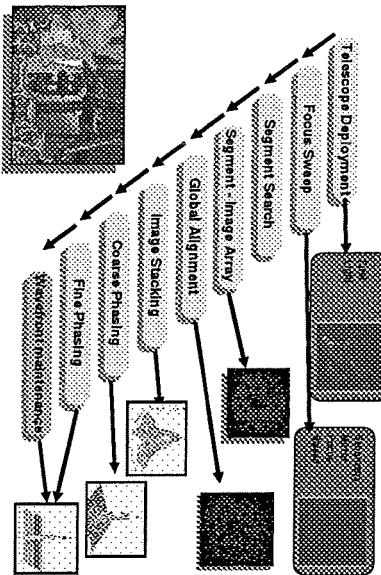
JWST Optical Path



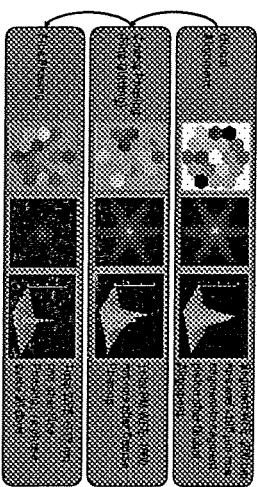
Off-Axis Annular FOV
Unvignetted FOV shown in black
OTE WFE < 131 nm rms within area bounded by black dashed line
The science instrument placement allocations are shown in blue



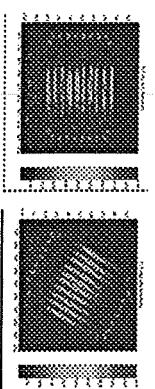
JWST Mirror Phasing



Wavefront Sensing & Control (WFS&C)



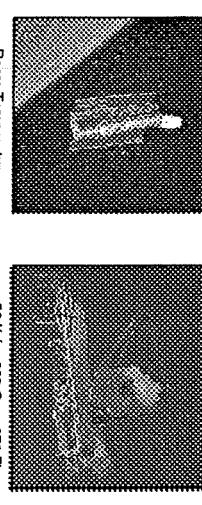
Kick Demonstration of WFS&C



WFS data taken without any PCS feedback to demonstrate the performance of the WFS.

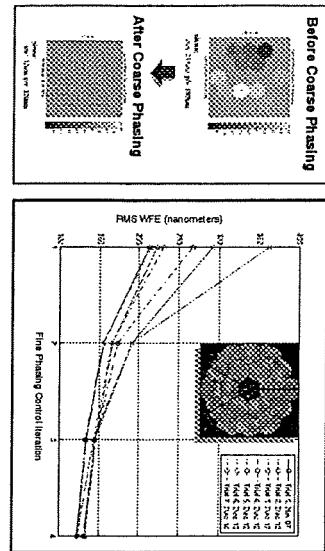
JWST Expands on HST Capabilities

HST: 2.4 m diameter Primary Mirror JWST: 6.5 m diameter Primary Mirror



• JWST has $7x$ the light gathering capability of the Hubble Space Telescope

• JWST operates in extreme cold to enable sensitive infrared light collection

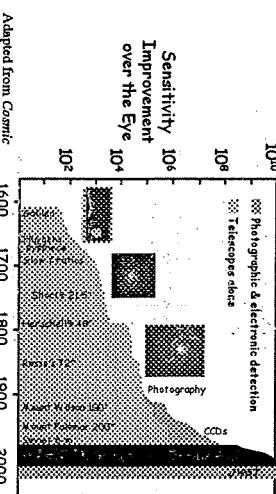


JWST Phasing Algorithms Demonstrated

Coarse Phasing
→ Fine Phasing
(segment to segment
pivot)

How to win at Astronomy
Aperture = Sensitivity

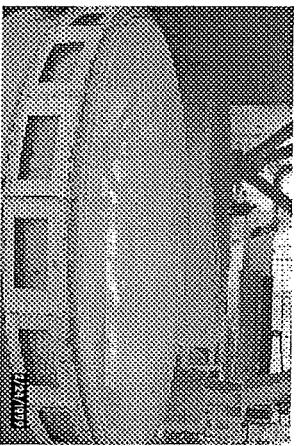
Big Telescopes with Sensitive Detectors In Space



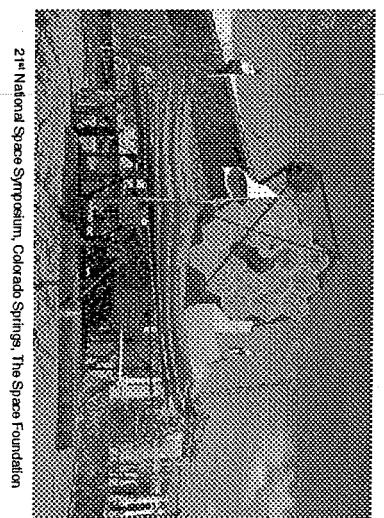
Adapted from Cosmic Discovery, M. Harwit

How big is JWST?

Full Scale JWST Mockup

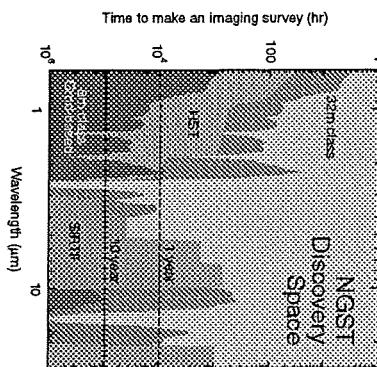


21st National Space Symposium, Colorado Springs, The Space Foundation



21st National Space Symposium, Colorado Springs, The Space Foundation

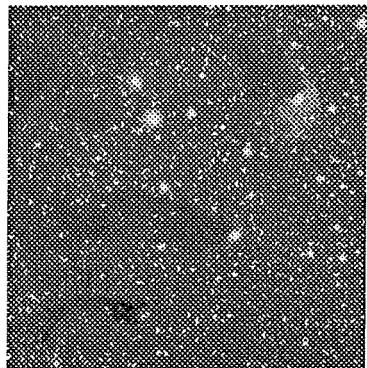
Why go to Space – Wavelength Coverage



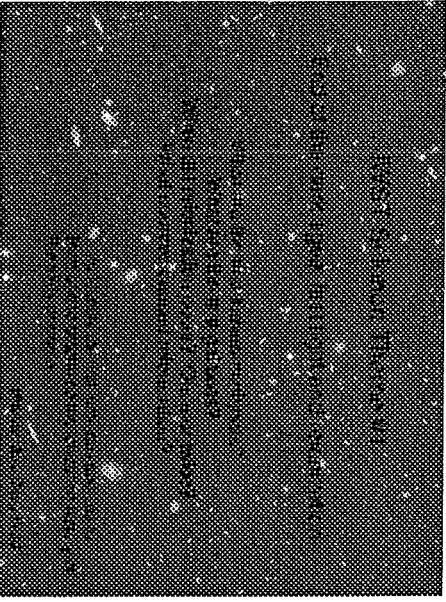
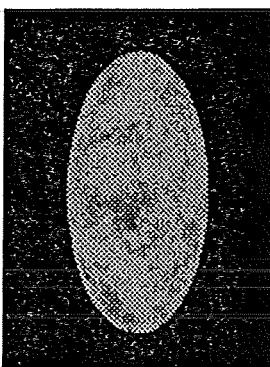
Infrared Light



Why Infrared?



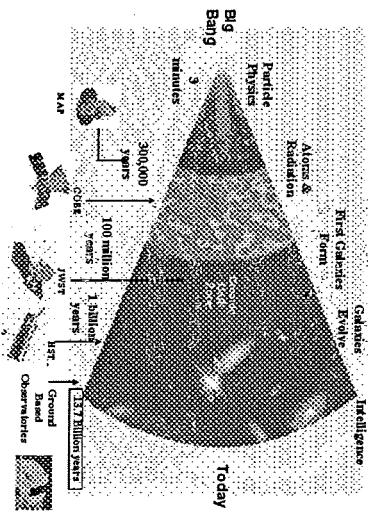
History of Time?



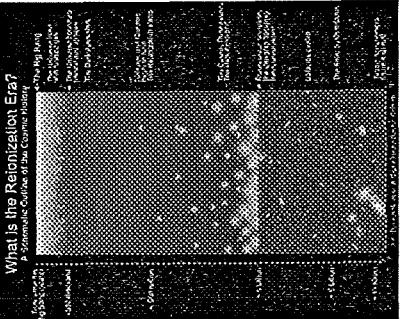
James Webb Space Telescope (JWST) is the next major space observatory. It will be the largest space telescope ever built, with a primary mirror 6.5 meters in diameter. It will be launched in 2018 and will orbit the Sun at a distance of about 1.5 million kilometers from Earth. It will be used to study the early universe, galaxies, stars, and planets.

Parameter	Value
Primary Mirror Diameter	6.5 meters
Telescope Length	13.5 meters
Telescope Mass	8.2 tonnes
Telescope Power	12.5 kilowatts
Telescope Temperature	-233 degrees Celsius
Telescope Orbit	1.5 million kilometers from Earth
Telescope Launch Date	2018

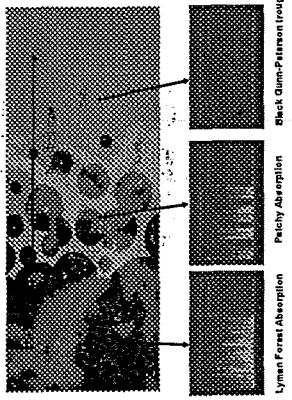
A Brief History of Time



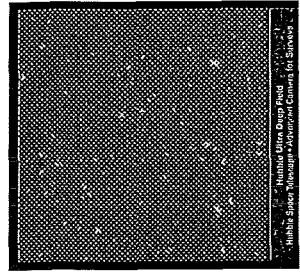
When and how did reionization occur?



First Light: Observing Reionization Edge.



End of the dark ages: first light and reionization

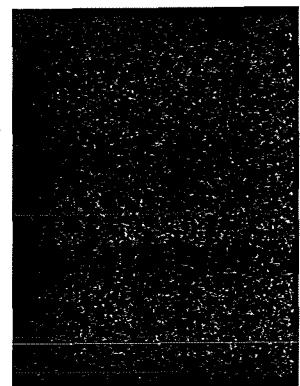


First galaxies are small & faint
Light is redshifted into infrared.
Low-metallicity, massive stars.
SNeI GRBs!
JWST Observations
Ultra-Deep NIR survey (1.4-1.6 μ m),
spectroscopic & Mid-IR
confirmation.

First Light

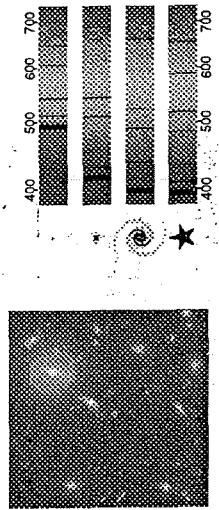
What did the first stars galaxies to form look like?

We don't know, but models suggest first stars were very massive!



Infrared Light

Light from the first galaxies is redshifted from the visible
into the infrared.



Hubble Deep Field

Hubble Ultra Deep Field

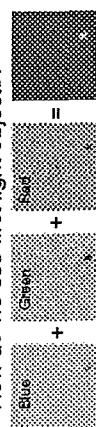
Hubble Space Telescope - Ultraviolet Camera for Surveys

2004

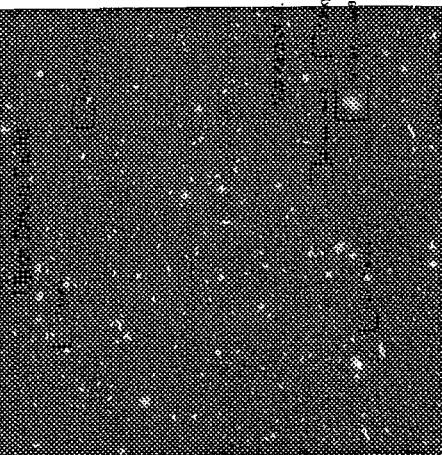
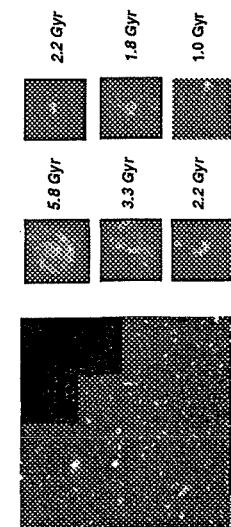
Hubble Space Telescope - Advanced Camera for Surveys

2007

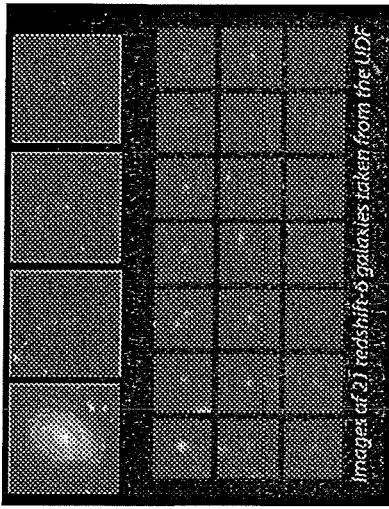
How do we see first light objects?



Deep Imaging: Look for near-IR drop-outs



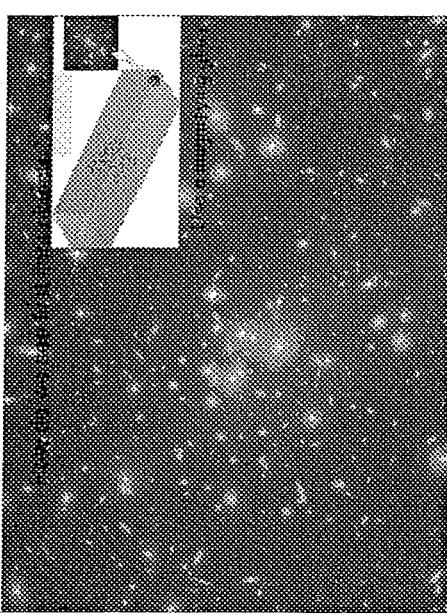
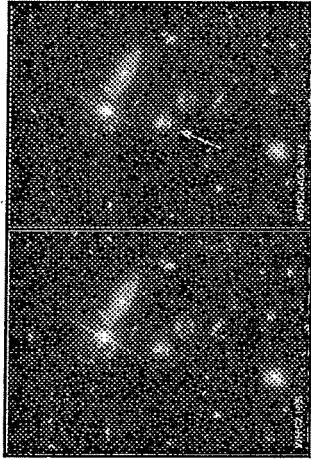
New Results from UDF



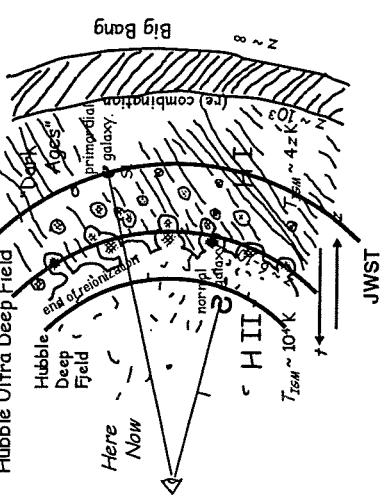
Images at 1.1 redshift galaxies taken from the UDF

How do we see first light objects?

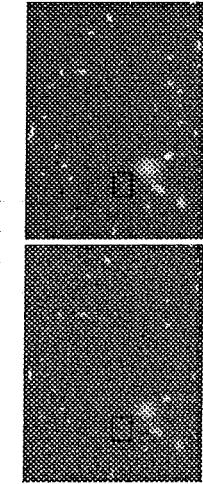
The first stars may be detected when they became bright supernovae. But, they will be very rare objects!



The Renaissance after the Dark Ages



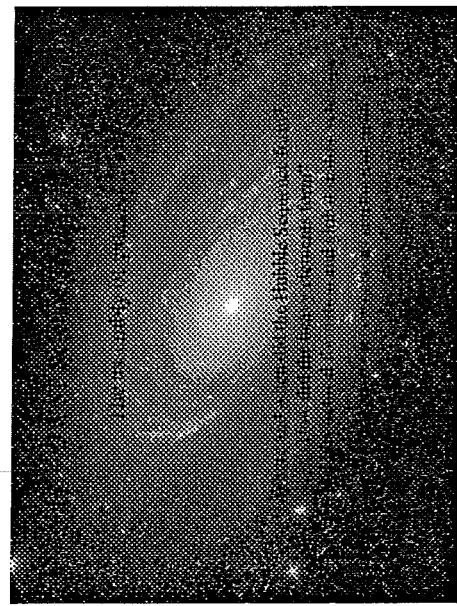
Sensitivity Matters



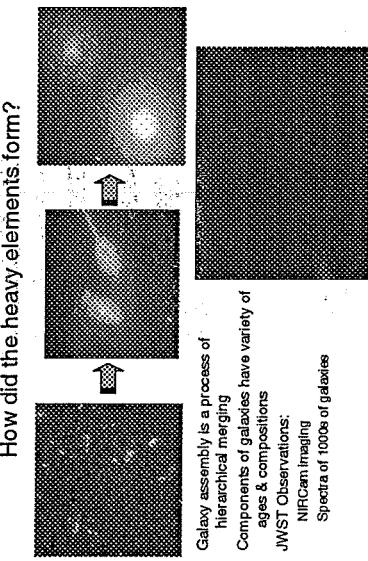
GOODS CDFS ~ 13 orbits



HUDF ~ 400 orbits

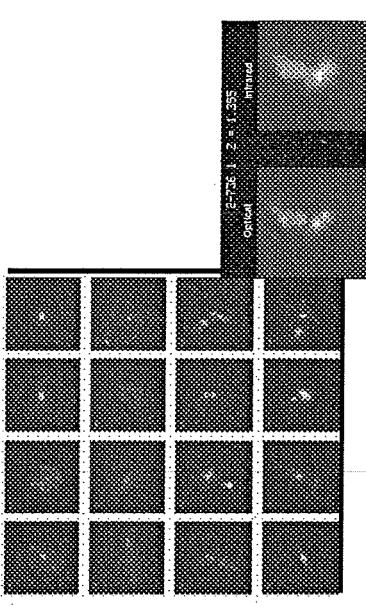


Where and when did the Hubble Sequence form?



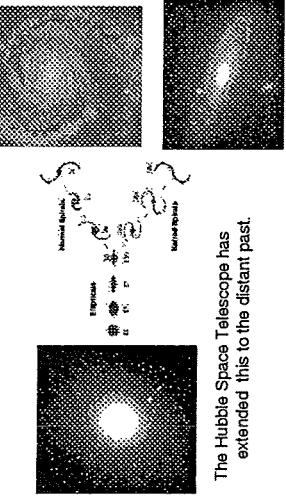
Galaxy assembly is a process of hierarchical merging
Components of galaxies have variety of
ages & compositions
JWST Observations:
NIRCam imaging
Spectra of 1000s of galaxies

Distant Galaxies are "Train Wrecks"



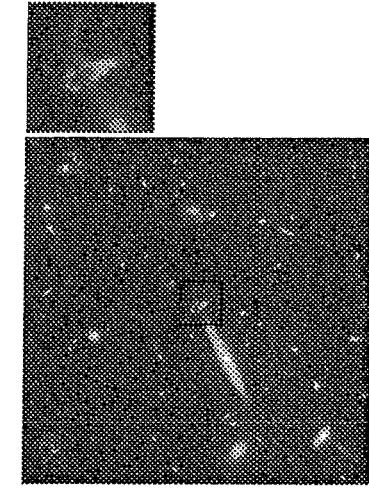
The Hubble Sequence

Hubble classified nearby (present-day) galaxies
into Spirals and Ellipticals.



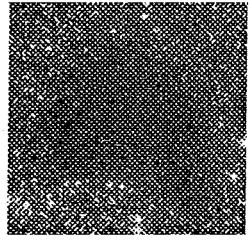
The Hubble Space Telescope has
extended this to the distant past.

Unusual objects



How do proto-stellar clouds collapse?

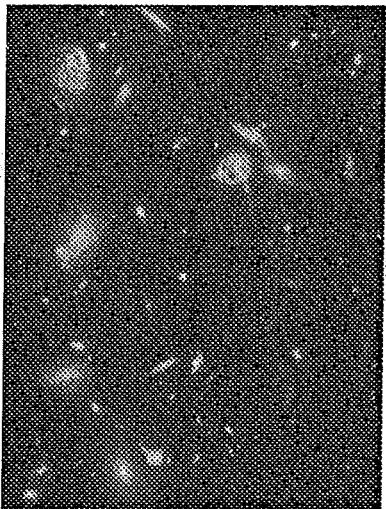
Stars form in small regions collapsing gravitationally within larger molecular clouds.



Infrared sees through thick, dusty clouds
Proto-stars begin to shine within the clouds, revealing temperature and density structure.

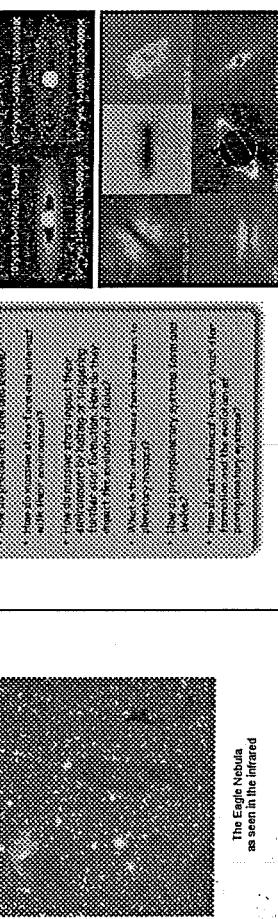
JWST Observations:
Deep NIR and MIR imaging of dark clouds and proto-stars

Clusters of Galaxies

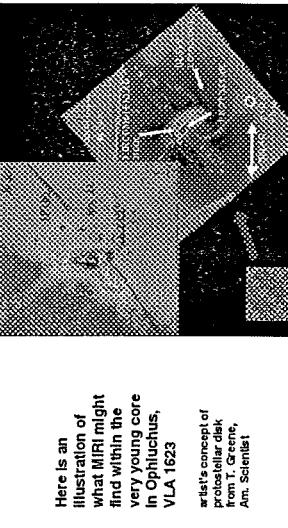


How does environment affect star-formation?

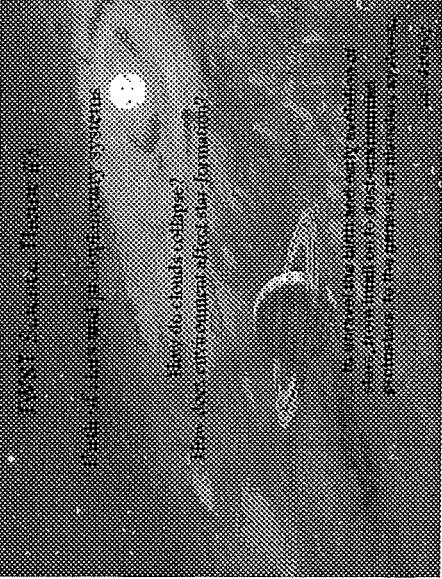
Massive stars produce wind & radiation
Either disrupt star formation, or causes it.



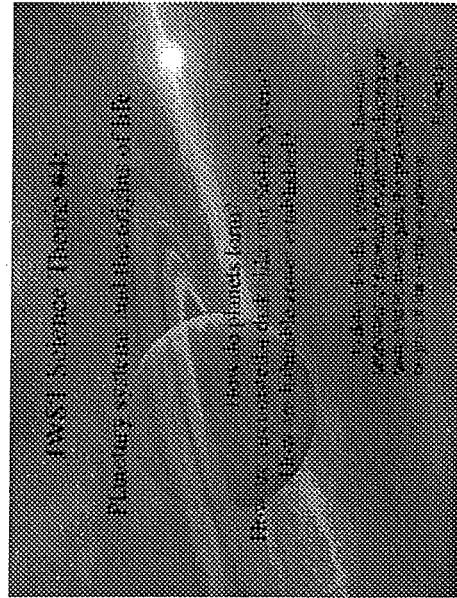
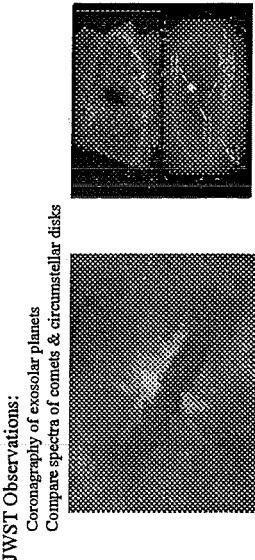
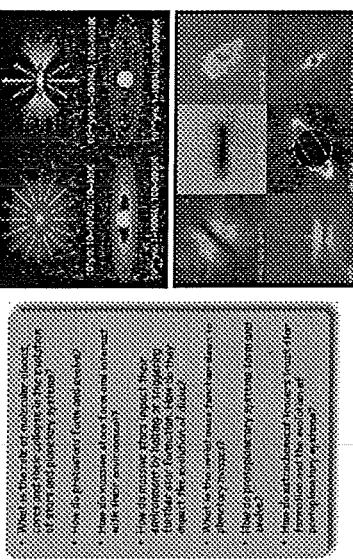
How are circumstellar disks like our Solar System?



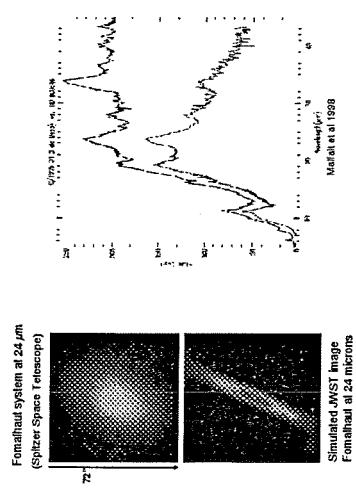
approximate field for JWST NIRSpec & MIRI
Integral field spectroscopy



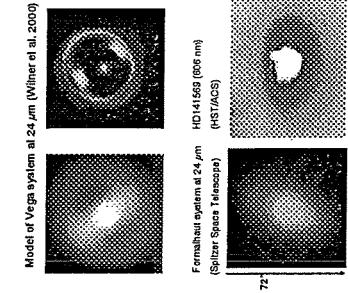
Birth of Stars and Proto-planetary Systems



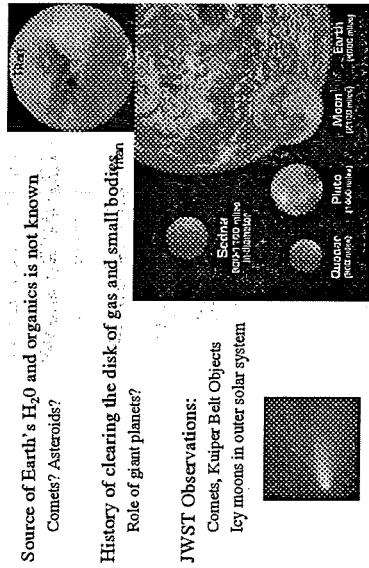
Planetary Systems and the Origins of Life



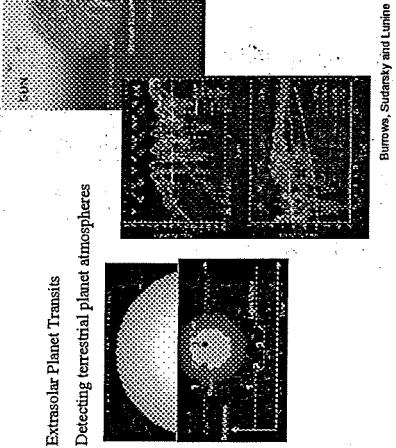
Planetary Systems and the Origins of Life



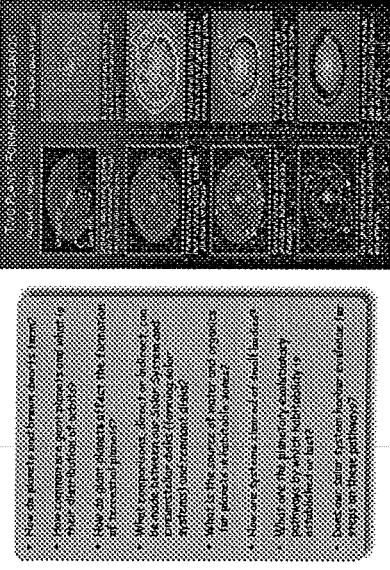
How are habitable zones established?



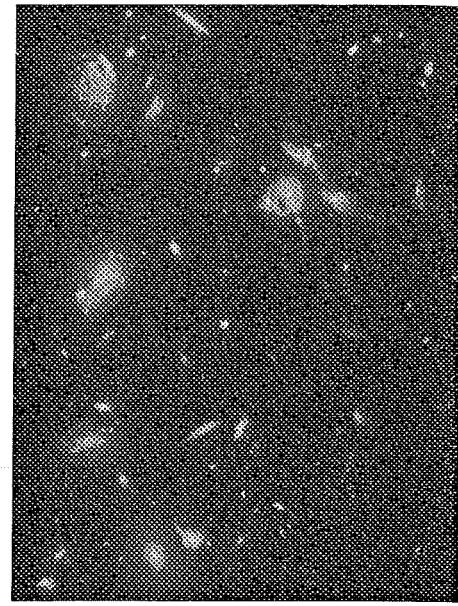
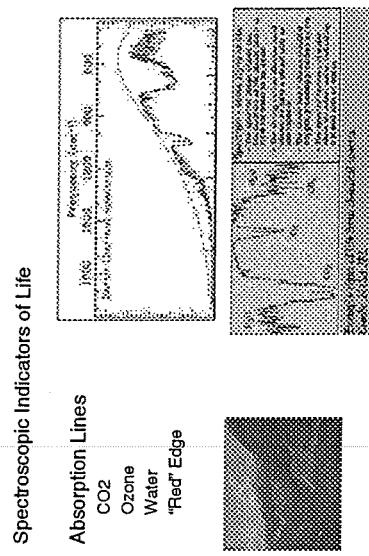
Atmospheres of Extrasolar Planets



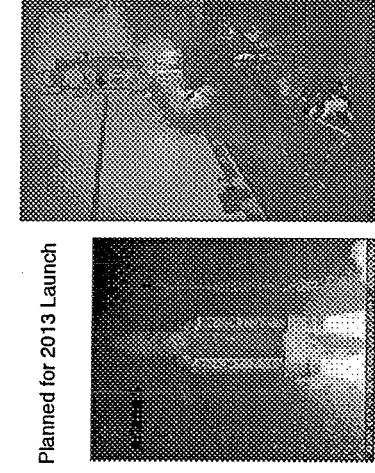
Planetary Systems and the Origins of Life



Bio Markers



Countdown to Launch



Any Questions?

